Patent Claims

1. A transmission filter apparatus for spatially dependent intensity filtering of an incident light distribution, comprising:
   at least one retardation device (23, 720, 920) that can be operated in transmission for the purpose of producing a spatially dependent retarding effect on the light of the incident light distribution, in which the retardation device (23) can be driven in order to produce a temporally variable, spatially dependent retarding effect, as well as having at least one polarization filter arrangement (24, 730) arranged in the light path downstream of the retardation device.

2. The transmission filter apparatus as claimed in claim 1, wherein the retardation device (23, 720, 920) can be continuously driven in order to produce a temporally variable, spatially dependent retarding effect.

3. The transmission filter apparatus as claimed in claim 1 or 2, wherein the retardation device comprises a cell arrangement (23) with a multiplicity of cells that can preferably be driven individually and independently of one another.

4. The transmission filter apparatus as claimed in claim 3, wherein the cell arrangement (23) comprises at least one nonlinear optical crystal (63, 163) for producing a linear electro-optic effect (Pockels effect) in the light passage direction of the incident light distribution.

5. The transmission filter apparatus as claimed in claim 4, wherein the nonlinear optical crystal (63, 163) is transparent to light in a wavelength region below 200 nm.

6. The transmission filter apparatus as claimed in claim 4 or 5, wherein the nonlinear optical crystal (63, 163) consists essentially of beta barium borate (BBO), potassium hydrogen phosphate (KDP), deuterated potassium hydrogen phosphate (DKDP) or lithium triborate (LBO).

7. The transmission filter apparatus as claimed in one of claims 4 to 6, wherein the nonlinear optical crystal (63, 163) is designed as a plane plate that completely covers the region of the incident light distribution and has a first and a second plate face (64, 65).

8. The transmission filter apparatus as claimed in claim 7, wherein in order to produce a cell arrangement (23) a plurality of first electrodes (61) electrically separated from one another are mounted on the first plate face (65), and a plurality of second electrodes electrically separated from one another are mounted on the second plate face (64), and first and second electrodes are assigned to one another in pairs in order to form a plurality of electrode pairs electrically separated from one another, each electrode pair defining a cell of the cell arrangement.

9. The transmission filter apparatus as claimed in claim 7, wherein in order to produce a cell arrangement a plurality of first electrodes (61) electrically separated from one another are mounted on the first plate face, and at least one second electrode (62) is mounted on the second plate face, a number of first electrodes (61a, 61b) being assigned a common second electrode (62).

10. The transmission filter apparatus as claimed in claim 7, wherein in order to produce a cell arrangement a plurality of first electrodes (61) electrically separated from one another are mounted on the

first plate face, and the second plate face has a single second electrode (62) to which the plurality of first electrodes (61) are assigned.

11. The transmission filter apparatus as claimed in one of claims 8 to 10, wherein the electrodes (61) electrically separated from one another are arranged on the crystal at a spacing from one another that is large compared with the plate thickness of the nonlinear optical crystal (63, 163).

12. The transmission filter apparatus as claimed in one of claims 8 to 11, wherein the electrodes (61, 62, 161, 162) are substantially free from regions (material tips) causing high field strengths.

13. The transmission filter apparatus as claimed in one of claims 8 to 12, wherein at least one electrode (61, 62, 161, 162) has an antireflection layer.

14. The transmission filter apparatus as claimed in one of claims 8 to 13, wherein at least one electrode (61, 62, 161, 162) is designed as a grid electrode (70) with a plurality of webs (72) made from electrically conducting material and with a high transparent area fraction.

15. The transmission filter apparatus as claimed in one of claims 8 to 14, wherein the electrodes (61, 62, 161, 162) are designed to be partially transparent in such a way that the transmission loss that is caused in the incident light distribution by the electrodes (61, 62, 161, 162) is less than 20% upon passage through the cell arrangement.

16. The transmission filter apparatus as claimed in one of claims 8 to 15, which is assigned a control device (60) for producing electrical potential differences, which can be set independently of one another, between in each case one of the first electrodes (61), electrically separated from one another, of the first plate face (65), and an assigned electrode (62) of the second plate face (64).

17. The transmission filter apparatus as claimed in either of claims 1 or 3, wherein the retardation device comprises at least one retardation element (720, 920) made from a stress birefringent material, and a stressing device (930) having at least one actuator, acting on the retardation element, for setting a prescribable stressed state of the retardation element in accordance with a prescribable spatial distribution.

18. The transmission filter apparatus as claimed in claim 17, wherein the retardation device has only a single retardation element (720, 920), particularly in the form of an essentially plane-parallel plate.

19. The transmission filter apparatus as claimed in claim 17 or 18, wherein the stressing device (930) has at least one actuator pair with a pair of actuators that are arranged diametrically opposite one another with reference to a central axis (925) of the retardation element.

20. The transmission filter apparatus as claimed in claim 18 or 19, wherein the stressing device (930) comprises a number of actuator pairs that can be driven independently of one another and preferably form a cruciform arrangement or star arrangement of actuators.

21. The transmission filter apparatus as claimed in one of claims 17 to 20, wherein the stressing device (930) is designed in such a way that it is possible to set stress distributions that exhibit a multiple radial symmetry with reference to a central axis of the retardation element, in particular a 2-fold, 4-fold, 6-fold or 8-fold radial symmetry.

22. The transmission filter apparatus as claimed in one of the preceding claims, wherein the retardation device is movably mounted, and the retardation device is assigned a movement device for moving the retardation device relative to other parts of the transmission filter apparatus, the movement device preferably being designed as a rotation device for rotating the retardation device about an axis of rotation that in the case of a transmission filter apparatus installed in an optical system preferably coincides with an optical axis of the optical system.

23. The transmission filter apparatus as claimed in one of the preceding claims, wherein the retardation device can be exchanged, the transmission filter apparatus being assigned a changing device for interchanging a first retardation device with a first spatially dependent retarding effect against at least one second retardation device with a second spatially dependent retarding effect that differs from the first retarding effect.

24. The transmission filter apparatus as claimed in one of the preceding claims, which comprises a polarizer arrangement (740) arranged in the light path upstream of the retardation device, as a result of which an at least partially polarized incident light distribution that strikes the retardation device can be produced from unpolarized light.

25. The transmission filter apparatus as claimed in one of the preceding claims, wherein the polarization filter arrangement comprises at least one thin film polarizer (24).

26. The transmission filter apparatus as claimed in one of the preceding claims, wherein the polarization filter arrangement comprises at least one transparent plane plate that is arranged substantially at the Brewster angle with reference to the incident light.

27. The transmission filter apparatus as claimed in one of the preceding claims, wherein the polarization filter arrangement comprises at least one polarization splitter block with a polarization splitter layer that is enclosed between transparent material and is arranged substantially at the Brewster angle with reference to the incident light.

28. An illumination system for a microlithography projection exposure machine for illuminating an illumination field (53) with the aid of the light of a primary light source (2), having a pupil shaping unit for producing a prescribable light distribution in a pupil plane (9) of the illumination system, wherein at least one transmission filter apparatus (22) as claimed in one of claims 1 to 25 is provided.

29. The illumination system as claimed in claim 28, wherein the transmission filter apparatus (22) is provided in or in the vicinity of a plane of low numerical aperture, preferably in or in the vicinity of a plane of numerical aperture < 0.1, particularly preferably in or in the vicinity of a pupil plane (9, 18) of the illumination system.

30. The illumination system as claimed in claim 28 or 29, which comprises no light mixing unit for homogenizing the illuminating light.

31. The illumination system as claimed in one of claims 28 to 30, wherein a regulating unit (59) connected to a control device (60) and to the pupil shaping unit is provided for tuning the spatially dependent intensity filtering to the light distribution in the pupil plane (18).

32. The illumination system as claimed in claim 31, wherein the control device (60) is designed in such a way that in order to produce a homogenizing effect it enables the transmission filter effect to be set to the minimum intensity value of the incident light distribution.

33. An exposure method for exposing a substrate arranged in the region of an image plane (55) of a projection objective with at least one image of a pattern, arranged in the region of an object plane of the projection objective, of a mask, comprising:
illuminating the pattern with the aid of illuminating radiation from an illumination system as claimed in one of claims 26 to 30 in order to produce radiation modified by the pattern; and
transirradiating the projection objective (51) with the aid of the radiation modified by the pattern in order to produce an output radiation directed onto the substrate,
the intensity distribution of the illuminating radiation in the object plane (53) of the projection objective (51) being variably set as a function of space and time with the aid of the transmission filter apparatus (22, 710).

34. The exposure method as claimed in claim 33, wherein the illumination system has a pupil shaping unit at which a first light distribution is firstly set, and a first spatially dependent intensity filtering is undertaken at the transmission filter apparatus (22), and thereafter a second light distribution is set at the pupil shaping

element and a second spatially dependent intensity filtering is undertaken at the transmission filter apparatus (22).

35. The exposure method as claimed in claim 33 or 34, wherein the intensity distribution of the illuminating radiation is set with the aid of the control device (60) to the minimum intensity value of the incident light distribution in order to produce a homogenizing effect.

36. A retardation device for the spatially dependent retardation of an incident light distribution, having:
at least one cell arrangement (23), that can be operated in transmission, for producing a spatially dependent retarding effect on the light of the incident light distribution, it being possible to drive the cell arrangement (23) in order to produce a temporally variable, spatially dependent retarding effect.

37. The retardation arrangement as claimed in claim 36, characterized by the features of the characterizing clause of at least one of claims 3 to 16.

38. A retardation device for the spatially dependent retardation of an incident light distribution, having:
at least one retardation element, made from stress birefringent material, that can be operated in transmission, and a stressing device (930) having at least one actuator, acting on the retardation element, for setting a prescribable stressed state of the retardation element in accordance with a prescribable spatial distribution, it being possible to drive the retardation device in order to produce a temporally variable, spatially dependent retarding effect.

39. The retardation device as claimed in claim 38, characterized by the features of the characterizing clause of at least one of claims 17 to 21.
